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SOLAR ECONOMIC ANALYSIS: AN ALTERNATIVE APPROACH

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ABSTRACT

This paper examines from a critical perspec-
tive conventional economic analysis which
utilizes the discounted present value cri-
terion. It is found that this technique has
a number of limiting characteristics which
contribute to the lack of general usage of
economic analysis for evaluating passive solar
installations. Within this context we suggest
an alternative approach for determining the
economic desirability of such investments.
This latter method, compound future worth
analysis, is found to be both more under-
standable and flexible.

1. INTRODUCTION

Conventional economic analysis of energy con-
serving capital investments is usually based
upon cash flow analysis: that is, the yearly
cash flows associated with charges due to and
savings derived from a particular investment.
The discounted present value (DPV) technique
is used to convert non-uniform net cash flows
into a net present value which reduces the
lifetime stream of the benefit-cost differen-
tial to a lump sum dollar amount expressed
in this year's dollars. The net present val-
ues of alternative solar investments are then
compared, and particular solar systems are
often sized to insure the largest possible
net present value over the assumed system
life or ownership period. Oftentime, the net
present vlaue criteria conflicts with other
objectives, including favorable payback per-
iods, comfort considerations, etc. Notwith-
standing these problems, the DPV technique
has other limitations that have not been
addressed or recognized by the solar commu-
nity.

(a) DPV analysis defies intuitive logic
because it effectively moves events back into
time, whereas the natural order is for time
to move forward.

(b) Most individuals have expectations
concerning future events, and as time
passes their behavior often changes in
response to changing conditions. DPV
analysis imposes a structure upon the
dynamics of future behavior, and as such,
does not account for the true disposition
of cash flows over time.

(c) As dollar savings are realized
due to lower energy usage, the savings in
reality are not treated as separable in
personal consumption (goods and/or ser-
vices) or personal savings. DPV analy-
sis cannot easily allow for the separa-
tion of these income allocations which
carry different valuation weights for
each individual.

(d) Common experience shows that
the concept of discounting is difficult
to grasp by most design professionals.
This is not meant to imply that the de-
sign community cannot understand the
principles; rather, it points to the
need for an alternative approach that is
perhaps more understandable and not sub-
ject to the above drawbacks.

In this paper we suggest the use of com-
pound future worth (CFW) analysis for
evaluating alternative investments. The-
oretically, CFW analysis gives the same
results as would DPV analysis, but the
value of realized dollar "savings" is
projected into the future; that is, the
CFW technique indicates the investment
value at the end of the period, as
opposed to the beginning of the period.
By using this approach "savings" can be
treated as spent immediately of rein-
vested for withdrawal at a future period
in time, both of which have secondary
energy use and economic impacts.

The paper is structured as follows. In
the next section we develop the relation-
ship between DPV and CFW. Section 3 out-
lines a particular empirical example. In
Section 4 comparative results which demon-
strate the inherent flexibility of the CFW
approach are presented. Concluding remarks
are offered in the final section.

2. DECISION CRITERIA

The mathematical statement of the DPV decision rule for any investment using end of year accounting is

$$DPV = \sum_{t=1}^{T} NCF_t \cdot \left(\frac{1}{1+r}\right)^t$$

where:

NCF_t = net cash flow or investment returns minus cash outlays in year t

r = rate of discount or interest

T = period of financial analysis.

Alternatively, the CFW rule is represented as

$$CFW = \sum_{t=1}^{T} NCF_t \cdot (1+r)^{T-t} .$$

Therefore, the relationship between these decision criteria is

$$DPV \cdot (1+r)^{T} = CFW.$$

Since $(1+r)^{T}$ is a constant for a specified period of analysis then CFW is a constant multiple of DPV; hence, the relative ranking of investments (alternative investments or different sizes of the same investment) will be identical under either decision rule. To this date, the solar community has shown a penchant for using DPV calculations to the exclusion of the CFW approach although, as was indicated in the introduction, DPV possesses many undesirable properties. The following sections will demonstrate that the CFW approach is both more flexible and manageable in its ability to incorporate various behavioral and political changes in the dynamic structure.

3. SPECIFICATION OF EXAMPLE

The specific passive solar investment under consideration is a hybrid design -- 60% double glazed 12" water wall combined with 40% double glazed direct gain -- with R-4 night insulation located in Dodge City, Kansas (5,046 heating degree days). The heat loss factor for the reference home is assumed to be 7420 Btu/DD. The performance characteristics of the system as defined by required load-collector ratios (Btu/DD-ft²g) and collector areas for specified solar heating fractions are listed in Table 1 [1].

Table 1. Performance Characteristics

Solar Fraction	.20	.30	.40	.50	.60	.70	.80	.90
Load/Collector Ratio	97.6	60.1	40.7	30.3	23.5	18.3	13.6	8.8
Collector Area	76	123	182	245	316	405	546	763

The relative economic viability of a particular passive design is highly dependent upon the set of financial parameters utilized in the analysis. However, this issue is not pursued here; rather, we concentrate on the relationship between CFW and DPV for a stipulated set of parameters. These are specified in Table 2.

Table 2. Financial Assumptions

Variable Cost of Passive Solar Investment ($/ft²g)	15.00
Fixed Cost of Passive Solar Investment ($)	0.00
Initial Electric Resistance Fuel Cost ($/10⁶ Btu delivered)	14.65
Inflation Rate (%)	7.0
Nominal Fuel Escalation Rate (%)	8.0
Nominal Interest Rate (%)	10.0
Down Payment Ratio (% of add-on cost)	15.0
Financial Analysis Period (yrs)	10.0
Mortgage Term (yrs)	30.0
Annual Operation and Maintenance (% of add-on cost)	1.0
Annual Property Tax and Insurance Rate (% of add-on cost)	2.0
Federal, State and Local Tax Bracket (%)	25.0
Resale Value Factor (% of add-on cost)	75.0
Auxiliary System Cost ($)	500.00
Operation and Maintenance Rate on Auxiliary System (% of cost)	.5

4. COMPARATIVE ANALYSIS

The comparative analysis is limited to an examination of only one passive solar investment. Within this context, optimally sizing the system remains the relevant consideration. In Table 3, DPV and CFW calculations are presented by solar fraction in 10% increments. As is illustrated each decision rule yields the result that the hybrid passive design should be employed to satisfy 50% of the residence's heating requirements. At this fraction both net present value and compound future worth are maximized. This confirms the mathematical result of consistency between the decision rules obtained above.

Table 3. Comparative Results

Solar Fraction	.20	.30	.40	.50	.60	.70	.80	.90
Discounted Present Value	438	649	710	739	694	485	-168	-1174
Compounded Future Worth	960	1277	1397	1454	1365	954	-330	-4170

In addition, it has been well established that DPV, and therefore optimal solar fraction, is quite sensitive to the prevailing discount rate. This is also the case for CFW calculations. For example,

a compounding rate of .02 corresponds to an optimal solar fraction of .6, whereas if a .2 compounding rate is used a 40% solar fraction is optimal. A high compound interest rate implies that the passive solar investor has alternative investment opportunities which yield high returns. Thus, solar feasibility is diminished as would be the case with a high discount rate in DPV analysis. An alternative example would be low interest loans for passive solar installations. In this case, passive would have a relatively high return due to its low interest cost and therefore solar feasibility would be heightened.

Private reinvestment behavior is usually incorporated into the DPV calcualtion as a parameter which remains fixed over time. But the individual may have investment options associated with positive net cash flows (savings minus costs) which yield differential returns over different time spans. For instance, reducing one's home mortgage (implying a return equal to the mortgage rate), investing in common stock, bonds, real estate, or other interest earning assets, both liquid (savings accounts, government bonds, gold) and illiquid (artwork, jewelry), are all opportunities that may be available to the private investor. How one dispenses with the positive cash flows will impact both the value and the feasibility of passive solar energy. The differential returns and time periods are easily incorporated into the CFW approach but the DPV formula becomes quite unmanageable as the variations increase.

In order to demonstrate the impact of private investment behavior on solar feasibility consider the following. The individual may decide to invest all the positive net cash flows in passbook savings as a rate of 7%. However, the negative net cash flows may be paid for partly (assume 50%) out of savings (implying an interest loss of 7% annually) and partly by reducing consumption expenditures (implying a loss of 0% in this example). Note that a zero return associated with consumption expenditures is merely illustrative. In this instance, the optimal solar fraction increases to .7 in the Dodge City example. Conversely, if the opposite behavior is assumed -- negative cash flows are taken entirely out of savings and positive cash flows are only partly (50%) invested at 7% -- then the optimal fraction falls to .3. The importance of this example is to show that if individuals apply differential rates of return to the various components of cash flows then solar feasibility will be altered.

Another set of changes which are difficult to incorporate into the DPV structure is midstream political or social movements which affect investment behavior. Individuals have expectations concerning future events, many related to impending political or social changes. For instance, the investor may ex-

expect that changes in federal monetary or fiscal policy may alter investment opportunities. Consider the case of a decline in inflation five years hence which is assumed to result in a reduction in the compounding rate from .12 to .07. Positive net cash flows which correspond to the later years are then subject to a lower rate of return. In the Dodge City example this expectation results in a 40% optimal solar fraction, a decline of 10% from the initial example case.

A final advantage of the CFW approach is its ability to provide information on secondary energy use patterns. That is, positive net cash flows associated with a solar investment may be invested or consumed. If energy intensive commodities are consumed then total energy savings associated with the initial solar investment may be reduced. This could result either from a change in one's entire consumption set (i.e., a particular income threshold is passed which allows the purchase of an alternative life styie) or increased consumption of the existing commodity set. Secondary energy impact analysis can be easily handled in the CFW structure and is the subject of continuing research.

5. CONCLUDING REMARKS

This paper began with the premise that existing economic analysis of passive solar investments has a number of limitations. These drawbacks have constrained the use of economic analysis in decisions concerning solar energy applications. In an attempt to increase the use of economics in solar investment decisions we have suggested the compound future worth approach as a replacement for discounted present value analysis. CFW is the more natural methodology since movement is forward rather than backward. Further, the CFW approach has a generality and flexibility not inherent in the DPV approach. This is evidenced by consideration of investment return differentials, private investment behavior, politically or socially induced changes, and secondary energy impact analysis.

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